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THE FAUNA AND PALEOECOLOGY OF A PENNSYLVANIAN SHALE

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ABSTRACT

The fauna and paleoecology of a late-Pennsylvanian shale which lies between beds of the Livingston Limestone in eastern Illinois is presented. The name Charleston Quarry shale is used informally for this shale in the area of the Charleston Stone Company quarry, northeast of Charleston, Coles Co., Illinois.

The fauna consists mostly of bryozoans, brachiopods and crinoids distributed throughout three distinct zones within the Charleston Quarry shale. This fauna inhabited an offshore quiet bottom area in a shallow, warm, marine epicontinental sea at a water depth of approximately 20 meters.

INTRODUCTION

The late Pennsylvanian Livingston Limestone is exposed by mining in the quarries of the Charleston Stone Company along the Embarrass River, northeast of Charleston, Illinois. The thickness of a gray shale, the Charleston Quarry shale, at the study site, a newly opened pit in the quarry complex (¼ SE., ¼ SE., ¼ SW., SEC. 32, T. 13 N., R. 10 E., Coles Co.), is 18 inches. It divides the Livingston Limestone into two distinct benches, each approximately 10 feet thick. The shale is fine grained, predominantly gray in color and occurs in three distinct zones: a bottom-most, heavy, dense shale in abrupt contact with the lower limestone bench, a middle shale zone of soft, thinly-bedded, greenish-gray deposit mottled with darker patches, and an upper zone of limey shale which grades into the upper limestone bench.

STRATIGRAPHY

The Livingston Limestone was named by Worthen (1875). This, with the included Charleston Quarry shale, is placed in the Bond Formation, McLeansboro Group, Pennsylvanian System of eastern Illinois (Kosanke et al., 1960).

The most useful summary of the Pennsylvanian geology of the study area can be found in Clegg(1959) who refers to the limestone containing the Charleston Quarry shale as the Millersville Limestone. But Kosanke et al. (1960) have classified the limestone east of the La Salle Anticline as the Livingston Limestone. A direct correlation between the Millersville and Livingston Limestones is noted by Clegg (1959) and Kosanke et al. (1960).

The Livingston Limestone is a gray to buff, extremely dense, crystalline rock extending with the Millersville Limestone through the deep part of the Illinois Basin. The Livingston Limestone reaches, in places, a total thickness of 50 feet or more. It is not quite so well developed on the southern flank of the Bellair-Champaign Uplift, the northernmost extent of the limestone and the location of this paper's study area. Several authors have mentioned a shale bed separating the Livingston Limestone into two benches, but no definitive study of this shale, the Charleston Quarry shale, has ever been published.

SAMPLING

Numerous samples of the Charleston Quarry shale were collected during the summer of 1973. The samples were taken from a newly opened pit in the quarry on the west side of the Embarrass River and compared to specimens from the paleobiology collection of Eastern Illinois University derived from Charleston Quarry shale obtained from an abandoned pit on the east side of the Embarrass River.

All of these samples were obtained from a complete stratigraphic sequence of shale. The shale was removed from the quarry for study. One shale sample somewhat in excess of 5 cubic feet was taken apart bedding plane by bedding plane and examined for fossils. Different types and numbers of fossils found in each of the three shale zone layers are summarized in Table 1. Analysis of these samples indicate no specific orientation of the fossils. Most fossils were articulated and showed no surface wear from transport.

PALEOECOLOGY

Any attempt to reconstruct past environment is difficult, since in few cases is the evidence clear and indisputable. This section will present the basic paleoecological data and assumptions used in an environmental reconstruction of the Charleston Quarry shale.

Lophophyllidium proliferum is a small, solitary rugose coral and the only coral found in the fauna. According to Hill (1956), rugose corals were apparently able to exist in numbers under conditions where large compound corals could not flourish, the sedimentary environments suggesting, perhaps, moderately deep seas with relatively low amounts of light. Ziegler, Cocks and Bambach (1968) suggested that the "cornucopia" shape and weight concentration on the outer curve of the rugose coral would have served to keep its mouth raised above the sediment surface without being firmly anchored

TABLE 1. Faunal composition and specimen occurrence in a 5 cu. ft. sample of the Charleston Quarry shale. R= rare, 1-3 specimens; P= present, 4-8 specimens; A= abundant, 9 or more specimens.

Species	bottom shale zone	middle shale zone	upper shale zone
Coral			
Lophophyllidium proliferum	R	R	R
Bryozoa			
Fenestrellina mimica	A	A	P
Fenestrellina modesta	A	A	P
Polypora sp.	P	P	-
Penniretepora sp.	R	R	R
Rhombopora lepidodendroides	A	R	R
Brachiopoda			
Inarticulata			
Orbiculoidea missouriensis	A	R	R
Articulata			
Derbyia crassa	-	R	-
Chonetinella flemingi	R	R	-
Kozlowskia splendens	A	A	A
Reticulatia huecoensis	-	P	-
Hustedia mormoni	P	P	P
Composita argentea	R	-	R
Neospirifer dunbari	A	P	A
Punctospirifer kentuckyensis	-	R	P
Crurithyris planoconvexa	R	P	R
Bivalvia			
Acanthopecten carboniferus	R	-	-
Gastropoda			
Glabrocingulum grayvillense (R*)	?	?	?
Platycerus sp.	-	P	-
Trilobita			
cf. *Ditomopyge*	-	R	R
Crinoids			
stemules and plate fragments	A	A	A

*One specimen of unknown zonation from the Paleobiology collection of Eastern Illinois University.

to the substrate by cementation. The trophic mode of such corals has been designated by Walker (1972) as a high level suspension feeder. L. proliferum specimens were unfragmented and showed no surface wear from transport.

The bryozoans of the fauna are of two morphological types: the upright fan-shaped members of the family Fenestrellidae (Fenestrellina mimica, Fenestrellina modesta and Polypora sp.) and the branching or ramose forms (Penniretepora sp. and Rhombopora lepidodendroides). No encrusting bryozoans are present in the Charleston Quarry shale, although specimens of encrusting bryozoans are to be found in the Upper Livingston Limestone bench.

Except for R. lepidodendroides, which is abundant in the upper shale zone, the upright fan-shaped fenestrelid colonies are more common than the branching forms. According to Ryland (1970) fenestrelids presumably evolved in response to a need for the filtration area of the colony to be as large as possible in habitats not subject to appreciable water movement. Walker (1972) classified the trophic mode of the branching bryozoans as high level suspension feeders. Preservation suggests a quiet water habitat with rapid burial and no transport after death.

Orbiculoidea missouriensis, the only inarticulate brachiopod in the fauna, had a pedicle apparently used for attachment to a substrate but was not found attached to any material in the Charleston Quarry shale.

Articulate brachiopods make up the majority of specimens of the fauna. With the exception of Composita argentea, with its large, heavy, biconvex shell and need of a firm substrate for attachment by its pedicle, all of the articulate brachiopods possessed a shell morphology that would have allowed them to live on a soft sediment.

Derbyia crassa had a slightly biconvex shell unlike most other strophomenids. According to Muir-Wood and Williams (1965), the shell was supposedly attached to a surface by cementation of the ventral umbo, having lost a functional pedicle. However, in the Charleston Quarry shale, this species is always found unattached to any surface. It may have been free-lying upon the bottom, not utilizing any cementation habit, but relying upon its small size, weight and broad surface area to prevent sinking. Chonetinella flemingi, with its concavo-convex shell morphology and valve edges growing upwards, away from the substrate, was well adapted to life on a soft substrate. In addition, C. flemingi's shell morphology would allow a rapid snapping of the valves to unbury the shell if covered too deeply by shifting sediment (Rudwick 1970). Kozlowskia splendens and Reticulatia huecoensis, productids equipped with spines to spread out their weight, have obvious adaptions to live on soft bottoms. Broken unattahed spines are common fossils in the Charleston Quarry shale and spine scars are present on all specimens of these productids. Hustedia mormoni and Crurithyris planoconvexa were of a small size and weight, have obvious adaptions to live on soft bottoms.

Walker (1972) described the trophic mode of the brachiopods as low-level suspension feeders. Most of the Charleston Quarry shale brachiopods had their shell margins nearly level with the bottom and filtered the water immediately above the bottom.

The only bivalve in the fauna was Acanthopecten carboniferus, represented by only two specimens in the upper shale zone. This pecten probably occupied about the same ecological niche as recent pectens if similar body form means similar function and thus, was a low level suspension feeder resting on the bottom and swimming when sedimentation or other factors threatened.

Two Archaeogastropoda were present: Glabrocingulum grayvillense and Platyceras sp.. G. grayvillense had a rhipidoglossa type radula suggesting a herbacious diet (Knight et al. 1960) while Platycerus was an ectocommensal upon crinoid calices.

A trilobite, cf. Ditomopyge, was represented by many entire pygidia. In only one instance was it also represented by disarticulated thoracic segments and genal spines. This predominance of pygidia suggests some type of differential preservation.

Only stemules and a few plate fragments of crinoids were present in the shale. The crinoid stemules were extremely abundant in all three shale zones and followed a general trend of decreasing diameter as one proceeded upward from the bottom shale zone. The stemules appeared to be of several morphological types. Crinoid identification without the entire organism is extremely difficult and was not attempted with these fragments.

DISCUSSION

Paleoecological reconstructions are confined to broad generalizations by the very limitations of the fossil record because preserved animals are not always representative of a complete fauna. The environmental interpretation of the Charleston Quarry shale presented here seems most consistant with the available data, but it is by no means the only interpretation possible.

During the Pennsylvanian period, the land that is now central Illinois underwent cyclic changes in sea level due to the constant sinking of the Illinois Basin. This sinking basin led to periods of land submergence under a shallow sea. It was the transgression of these waters over the site of the present Charleston Stone Company quarry that allowed the Charleston Quarry shale to be deposited.

Variations in cyclically deposited sedimentary rocks and their included faunas usually reflect differences in water depth. The depth of water over a habitat and its distance from shore are related to the abundance and diversity of the fauna found there. Marine organisms increase in abundance and diversity from tidal flat environments toward offshore, shallow subtidal environments. Ecological conditions are less variable and more stable in subtidal offshore environments than in the harsher nearshore environments

(Walker and Laporte 1970). Stevens (1971) has devised a method of determining water depth by the number of brachiopod genera present in a fauna. Stevens believes that more brachiopod genera are found in the more stable deeper waters offshore than in the less stable shallower waters nearshore. Using the thin coal seam seen in the study pit beneath the Livingston Limestone as a starting point of a sedimentary sequence in the quarry and the upper Livingston Limestone bench as the end point, one can estimate the changes in water depth. The thin coal seam represents the remains of a swamp present before the transgression of an epicontinental sea. Above the coal is a three foot layer of dark gray shale which would represent the original shallow bottom of the sea. Water depth gradually increased and under a depth of 5-15 meters, the lower Livingston Limestone bench was deposited. This depth is arrived at from Stevens' (1971) views which relate the four genera of brachiopods present in the lower limestone bench; Composita argentea, Neospirifer dunbari, Kozlowskia splendens and a rhynchonellid, to a water depth of 5-15 meters. After the deposition of the lower Livingston Limestone bench, the water depth rapidly deepened and the sediment regime changed. This sudden change in water depth can be deduced from the abrupt contact between the upper surface of the lower Livingston Limestone and the bottom shale zone on the Charleston Quarry shale.

The water depth above the Charleston Quarry shale was over 20 meters, based on the presence of 10 genera of brachiopods. With the deposition of the Charleston Quarry shale, the water became shallower, due to a recession of the epicontinental sea. This was a gradual process as seen by the gradual gradation of the upper shale zone upwards into the upper Livingston Limestone bench. Although Mylius (1927) has described 9 genera of brachiopods in the upper Livingston Limestone bench, the authors and Eastern Illinois University's Paleozoology classes over several years, have found only five genera: Composita argentea, Neospirifer dunbari, Kozlowskia splendens, Punctospirifer kentuckyensis and a rhynchonellid. This would correspond to a depth of 5-15 meters, the same depth of deposition as the lower Livingston Limestone bench.

The upper Livingston Limestone bench is the end of the Pennsylvanian strata in the quarry as all intervening beds between the upper limestone bench and the Pleistocene deposits have been removed by post-Pennsylvanian erosion. Mylius (1927) has described sandstones, shales, slates and a thin limestone of later Pennsylvanian age above the upper Livingston Limestone bench to the south of the study area. This would seem to indicate the continuation of the typical Pennsylvanian cycle of deposition after the formation of the Livingstone Limestone.

Some other factors must also be considered in a paleoecological study: light penetration, water temperature, salinity, bottom condition, and food supply.

If light conditions now are similar to light conditions in the Pennsylvanian, then it is probable that some wave lengths of light were able to penetrate 20 meters of water to reach the bottom for some period of each day.

Water temperature is assumed to be warm in shallow epicontinental seas of the Pennsylvanian period.

Water salinity is influenced by many factors and there is no way to determine salinity beyond the presumed tolerance range of such a normal fauna as was found in the Charleston Quarry shale. There are no brackish water forms, such as Lingula, present so salinity is assumed to have been normal.

Many factors played a part in the determination of the bottom conditions of the three shale zones of the Charleston Quarry shale including water currents, suspended particles and sedimentation.

The Charleston Quarry shale is composed of fine mud and clay particles which would have required time to settle out of a quiet suspension. Any appreciable water movement would have inhibited the shale formation. The exclusion of water currents from the bottom could have occurred in three ways. First, the bottom could have been deep enough and far enough offshore to preclude any wave action. The water current necessary to carry the shale particles to the area of depositon was far enough above the bottom to insure that the bottom was relatively undisturbed. Second, the bottom could have been covered by a lush growth of vegetation that had reached a height which effectively inhibited bottom currents of a velocity necessary to disturb the shale deposition. Third, a combination of low velocity bottom currents and some vegetation might have excluded high velocity bottom currents. In any of these alternatives, the offshore location of the Charleston Quarry shale deposition area is reinforced because currents from the shore tend to carry small sediment particles making up shale the farthest from shore before depositing them.

A quiet bottom is postulated for shale formation as well as to accomodate certain aspects of fauna. First, the fragile bryozoan skeletons were not fragmented by transport nor was any surface wear observed on any other fossil. Second, the fossils were not directionally oriented indicating a current. Third, the morphology of fenestrellid bryozoans was presumably adapted to a quiet water habitat. All this, of course, does not mean that the water was still enough to be completely free of sediment. Instead, the water was well supplied with suspended fine particles of clay, mud and abundant organic food materials. The abundant food and sediment required the fauna to be composed of animals which had highly evolved mechanisms for sorting and rejection to separate their food from inorganic particles.

Sedimentation was not the same in all three shale zones. The bottom shale zone has thick bedding planes (.75-1.25mm) indicating that sedimentation was heavy when it did occur but was probably intermittent. The middle shale zone has thin bedding planes (.25-.50mm) indicating that sedimentation was probably constant. The upper shale zone is thinly bedded at its base (.30mm) but in the portion of the zone immediately below the upper limestone bench, there are no bedding planes. The upper shale zone is very limey indicating reworking and mixing of the shale and lime.

The relative firmness of the bottom was different in each of the three shale zones. The bottom shale zone was thin and dense since it offered sufficient anchorage for Composita argentea and large crinoids. The middle shale zone was probably a semi-ooze bottom with water filling the spaces between the fine shale particles. This was definitely a less firm substrate than the bottom shale zone and one on which C. argentea could not attach. The upper shale zone has the least number of species. This was probably a slightly firmer bottom than the middle shale zone. It contained C. argentea but whether this brachiopod attached during deposition of the upper shale zone or after mixing with lime had occurred is not clear. The upper shale zone had the crinoid stems of the smallest diameter. Perhaps this transitional zone from shale to limestone offered the least stable environmental conditions of the three shale zones.

The Charleston Quarry shale might be designated a Kozlowskia-Neospirifer community since these two genera were the most abundant and characteristic of the fauna. They also exhibited specializations, such as the spines of Kozlowskia and the wide wings of Neospirifer, that relate then to the soft bottom of the Charleston Quarry shale. There was no evidence of infaunal species in the community. No burrows or reworking of the sediments were found.

SUMMARY

The Charleston Quarry shale was formed of fine sediments in a quiet bottom habitat in 20 meters of water that was offshore in a warm epicontinental Pennsylvanian sea. Sedimentation varied from heavy and intermittent to light and steady during the deposition of the three shale zones. The relative firmness of the shale differed.

The fauna can be designated a Kozlowskia-Neospirifer community. The primary trophic mode was filter feeding on an abundant food supply. All of the fauna was epifaunal and a characteristic marine assemblage.

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